Effect of Citric Acid on Thickeners Used in Products for People Suffering Oropharyngeal Dysphagia

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***Abstract*—*Dysphagia is a digestive disorder recognized by the World Health Organization (WHO) in the International Classification of Diseases (ICD) characterized by the difficulty in forming or moving the bolus from the mouth to the oesophagus that can cause the passage of food into the respiratory tract. Foods for people with dysphagia are prepared with products that modify viscosity to make them safer when ingested. The aim of this work is to establish the interaction between citric acid, widely used by the food industry, with different thickeners, both first and second range, in order to check whether they fulfil the functions for which they have been designed. The time stability and viscosity as a function of the hydration time of six thickeners and their behavior in the temperature range between 25 and 50 °C were determined. Thickener concentrations up to a maximum of 6% were used in combination with 3acid concentrations (0.5, 1 and 2%). In distilled water, the sedimentation of first range thickeners and the gelification of second range thickeners were checked, as well as the change from non-Newtonian to Newtonian behaviour after the hydrolysis process in both types of thickeners. In the presence of citric acid, the behaviour of both types of thickeners was analogous. Second range thickeners have been found to be much safer than first range thickeners in modifying the viscosity of liquids for people with dysphagia due to the fact that they do not sediment. .*

***Keywords*—citric acid, dysphagia, gum, starch, thickener, viscosity.**

I. INTRODUCTION

Pulmonary aspiration is the passage of material generated in the stomach, esophagus, mouth or nose from the pharynx to the trachea and lungs. When this passage of material is related to the difficulty in moving food from the mouth to the stomach, it is known as dysphagia [1].

Dietary modifications should be individualized according to the type of dysfunction and the chewing and swallowing capacity of each patient. Thus, different consistency degrees have been standardized so that the patient can have the optimal diet and eat correctly ensuring that nutritional and water requirements are achieved. Consequently, the diet may vary from liquid to solid, through different degrees of consistency [2].

Although patients are sometimes unaware of the disorder, oropharyngeal dysphagia is a very common clinical condition, affecting more than 30% of stroke patients, 60-80% of patients with neurodegenerative diseases, 10-30% of adults over 65 years of age and more than 51% of elderly institutionalized patients [3].

Fluids are usually thickened to slow down their transit speed, to avoid aspiration of material into the respiratory tract and to improve transit into the oesophagus. However, names, level number of modification and characteristics vary within and between countries. In fact, over the past 30 years, as knowledge of dysphagia has grown, more technical definitions have emerged that delineate the difference between oesophageal and oropharyngeal dysphagia [4].

In October 2012, at the meeting of the European Swallowing Disorder Society in Barcelona, an initiative was developed that aims to achieve an international standardised terminology and definitions for textured modified foods and thickened liquids for individuals with dysphagia of all ages, in all care settings and all cultures. The result of this meeting was the formation of the International Dysphagia Diet Standardisation Initiative (IDDSI) [5].

In the experimental development of this publication, the classification of The National Dysphagia Diet (NDD) has been used, which is a way of objectifying the different degrees of consistency of diets through viscosity[6]. Thus, four categories of viscosity are distinguished:

a) Thin viscosity, water and beverages in general (1-50 cP);
b) Nectar viscosity, allows ingestion in the form of sips (51-350 cP)
c) Honey viscosity, allows ingestion with a spoon, and does not maintain its original shape and consistency (351-1750 cP)
d) Pudding viscosity, allows ingestion with a spoon, maintains its shape and consistency and cannot be drunk (>1751 cP).

In recent decades, there has been a rapid development of thickening agents used in the treatment of dysphagia. Initially, food-based thickeners such as potato starch, maize flour and rice cereal were used. Later, modified maize starch gained popularity, but more recently gums-based thickeners have become more popular due to their stability over time [7]. However, starch-based thickeners may not dissolve well in some liquids, may appear cloudy and may continue to thicken over time [8].

On the other hand, rubber-based thickeners appear to offer some advantages over starch-based products [9]. Unlike starch, gums (including xanthan gum) do not degrade with the amylase in the saliva, which allows the viscosity to remain stable. They are supposed to reach the desired viscosity quickly, which makes them very suitable for hot drinks, and have been shown to maintain stability in liquids over time [10].

Nowadays, a distinction is made between two types of thickeners, those containing starch and those not containing starch, although, in the first group, a distinction is usually made between those consisting only of starch and those that are mixtures of starch, and gums [11]. This type of thickener is called first-range and usually uses modified maize starch or a maltodextrin derived from maize.

Second-range thickeners are composed exclusively of gums and in some particular cases may contain a small amount of modified starch. They differ from the first range in that the amount of product to be used to obtain the desired viscosity is considerably lower.

The aim of this manuscript is to establish the influence of citric acid (E 330) on six commercial thickeners of plant origin. Based on previous experiences, it was determined at different concentration values: the temporal stability of the recently prepared samples; the Newtonian or non-Newtonian behaviour as a function of the rest time and its behaviour in the temperature range between 25 and 50°C [12, 13].

II. METHODOLOGY

The behaviour of six thickeners was determined, two of them first-range: Densiter® y Resource®; and four second-range: ViscoInstant®; Fresubin®, Clinutren® and Gelcarin®.The behaviour of these thickeners was studied in a neutral medium with distilled water and in an acid medium with citric acid. Citric acid (supplied by PANREAC with a degree of purity for analysis) was used for this purpose.

Samples were prepared at different concentrations of each thickening product in order to obtain samples of the four degrees of consistency accepted in the oropharyngeal dysphagia field (thin liquid, nectar, honey and pudding). At the same time, the concentration of citric acid was also modified for each concentration of thickening product. The acid concentrations studied were 0.5, 1 and 2%. The samples used had a volume of 650 mL and were prepared in triplicate expressing the concentration of thickener in % by weight. TABLE 1 shows the composition of each thickener used in this work.

TABLE 1
THICKENERS COMPOSITION

Product	Type	Origin	Composition
Densiter®	First range thickener	Plant	Corn starch
Resource®		Plant	Modified corn starch
Viscoinstant®	Second range thickener	Plant	Maltodextrin, xanthan gum and guar gum.
Clinutren®		Plant	Maltodextrin, xanthan gum, potassium chloride and may contain traces of milk
Gelcarin®		Plant	Carrageenan, potassium citrate and sucrose
Fresubin®		Plant	Modified tapioca starch, xanthan gum, maltodextrina, modified cellulose and natural aroma.

In the first-range thickenersthe formation of lumps was observed. Lumps are an added problem in the preparation of food for patients with dysphagia as they can cause problems in swallowing. To avoid as much as possible the formation of lumps, once the solvent (distilled water or citric acid solutions) was prepared, a constant agitation was maintained at 1000rpm while slowly pouring the thickener to be studied at room temperature.

The main objective of this project was to determine the viscosity at different temperatures of freshly prepared samples and after a 5-hour rest period. The temperature range was between 25 and 50ºC and the different experimental series differed by 5ºC.

Viscosities matching a thin viscosity, below 30 cP, were determined using a pre-calibrated Cannon Fenske 520 Viscometer, while for the remaining viscosity determinations a pre-calibrated Brookfield RTV31196 Rotational Viscometer was used. In

the case of the Cannon Fenske viscometer, it was imposed as a restrictive criterion that the difference between two consecutive measurements of the same sample should not exceed one second. Otherwise, the measurement was repeated. When operating the Brookfield RTV 31196 viscometer, the criterion imposed was to accept a maximum dispersion value of 3% between two consecutive measurements [14].The temperature of the samples was regulated with the aid of a Lauda E100 thermal bath. Once the measurements had been made on the freshly prepared samples, they were kept in refrigeration at 4ºC and the tests were repeated after 5 hours. The various samples were prepared by weighing the corresponding solute with a Scaltec SBC 33 analytical balance. A JW-3510 pH meter previously calibrated at the beginning of each session was used for the determination of pH. Three readings were taken once the sample was stabilized and the average value of the three readings was taken into account. Fig. 1 shows the block diagram followed during this process.

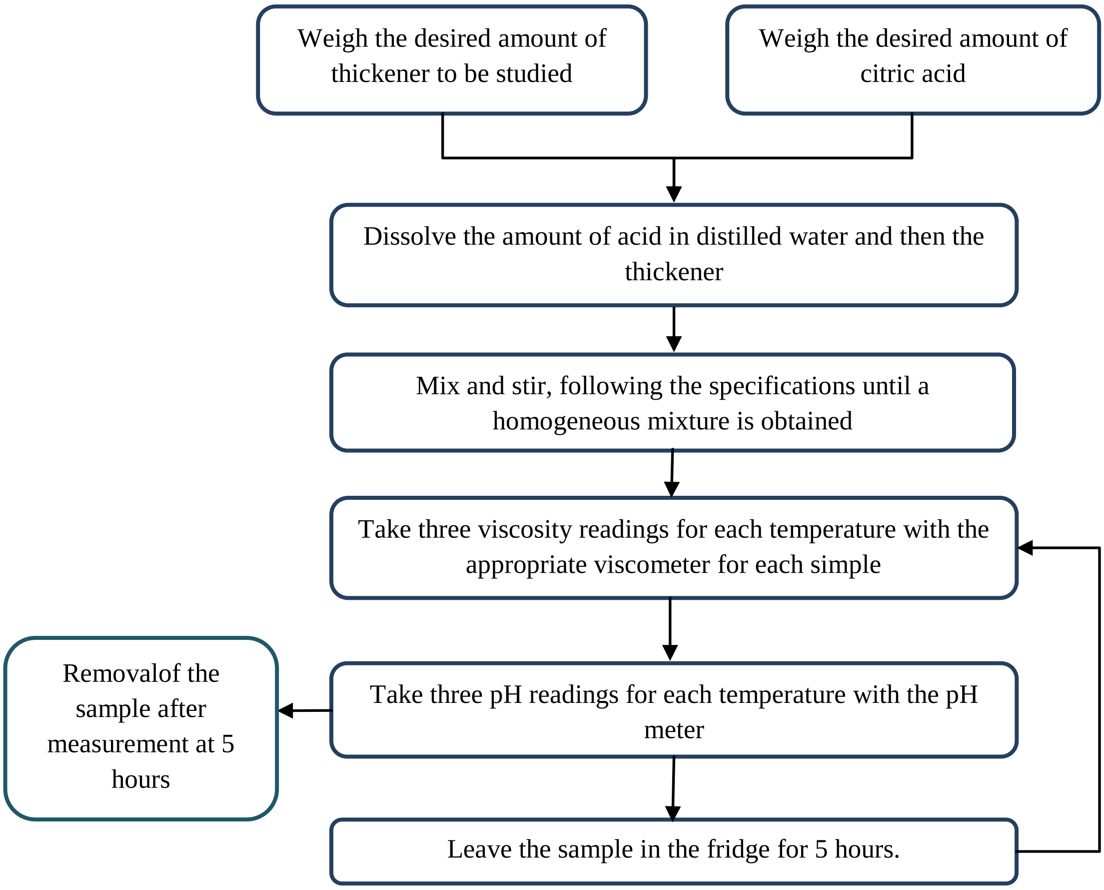

FIGURE 1: Sample preparation process

III. RESULTS

3.1 Temporal stability of the samples

The viscosity of the different thickeners was determined after the corresponding sample was homogenised. This homogenisation was necessary because a sedimentation process was observed in the samples of the two first-range thickeners, Densiter® and Resource®. This sedimentation was not observed in the samples of the second range thickeners, which remained stable indefinitely, forming gels.

Confirmation that this behaviour was due to the presence of starch was made through the Lugol test (iodine solution). For this purpose, samples were prepared at 1% of each thickener and the experiment was carried out at two temperatures, 25 and 90ºC.

As can be seen in Fig. 2, a positive result was obtained for the presence of starch in the first range thickeners. The result was in line with the composition of Densiter® (native starch) and Resource® (modified starch). The same intense colouring was obtained in the Clinutren® second range thickener, despite the fact that the technical data sheet for this thickener does not indicate the presence of starch (this unexpected behaviour was interpreted as an interference of the type of maltodextrin used).

The Viscoinstant® and Fresubin® thickeners showed a slight colouration indicating signs of starch. The technical data sheet for Fresubin® thickener does indicate the presence of starch, whereas for Viscoinstant® thickener there is no reference to the incorporation of this carbohydrate. Gelcarin® thickener showed a yellowish colouring in Lugol's test which does not indicate the presence of starch as indicated in its technical data sheet.

A

B

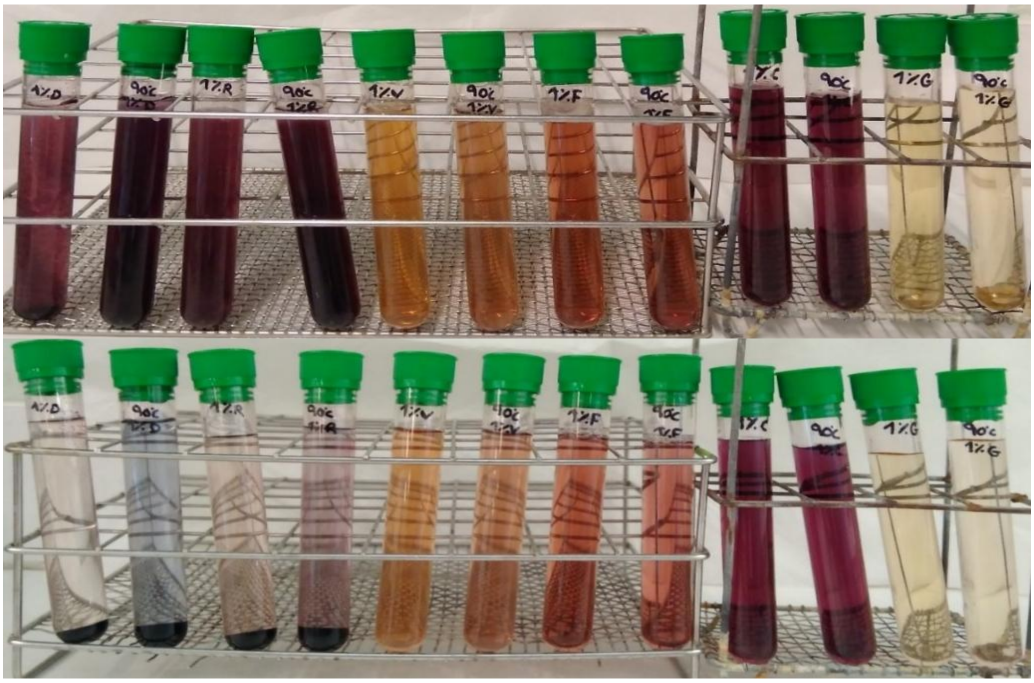

FIGURE 2: Lugol test with a concentration of 1% of all thickeners at 25ºC and 90ºC:a) Just performed b) Left to stand.

Only the samples of Densiter® and Resource® thickeners precipitated at both 25 and 90°C, while the rest of the Viscoinstant®, Fresubin®, Clinutren® and Gelcarin® thickeners did not. Consequently, it can be concluded that they only sediment the first-range thickeners when left to stand, as a result of the high percentage of starch present in their composition.

3.2 Degrees of consistency

The results obtained experimentally were structured according to the different degrees of consistency accepted by the (NDD) [6]. TABLE 2 shows the results obtained for each thickener.

TABLE 2
CONSISTENCY AS A FUNCTION OF CONCENTRATION.

	Type of Thickener	Thin Liquid 1-50 CP	Nectar 51-350 CP	Honey 351-1750 CP	Pudding>1751 CP
Densiter®	1st gamma	≤ 3%	4%	5%	≥ 6%
Resource®	1st gamma	≤ 3%	4%	5%	≥ 6%
Fresubin®	2nd gamma	< 0,3%	[0,3%-1%]	[2% - 3%]	≥ 3%
Viscoinstant®	2nd gamma	≤ 0,3%	0,5%	[1% - 2%]	≥ 3%
Clinutren®	2nd gamma	≤ 0,3%	[0,5%-1%]	[2% - 4%)]	≥ 4%
Gelcarin® (*)	2nd gamma	---	---	---	---

(*) ***Compound containing carrageenan. In the samples just prepared, the degree of consistency was always a thin. After being left to stand, it was systematically changed to honey or pudding consistency.***

As expected, as the concentration of thickener increased, the degree of consistency (viscosity) increased. However, first and second range thickeners behaved significantly differently: second range thickeners needed less thickener to reach the same degree of consistency. In fact, for the thin liquid and nectar consistency, 10 times more of a first-range thickener was needed

than a second-range thickener; for the honey consistency, 2.5 times more was needed and for the pudding consistency, twice as much as a second-range thickener was needed.

3.2.1 Thin liquid

A thin liquid consistency of up to 3% by weight was achieved with the first-range thickeners Densiter® and Resource®. In contrast, with the second-range thickeners Viscoinstant®, Clinutren® or Gelcarin®, this consistency was achieved only with a percentage of less than 0.3%. All thickeners prepared with distilled water in the thin liquid consistency showed a Newtonian behaviour, i.e. as the temperature increased the experimental value of the viscosity decreased.

When the thickeners were left to stand for 5 hours, the samples with the first-range thickeners showed higher viscosity values than the freshly prepared samples. This is the opposite of the second range thickeners which, when left to stand for 5 hours, presented lower absolute values of viscosity, with the exception of the Gelcarin® thickener whose composition is based on carrageenan and not on xanthan gum. In all cases, the viscosity values decreased with temperature, after the resting period. Fig. 3 shows the behaviour of a first-range thickener, Densiter®, and a second-range thickener, Viscoinstant®.

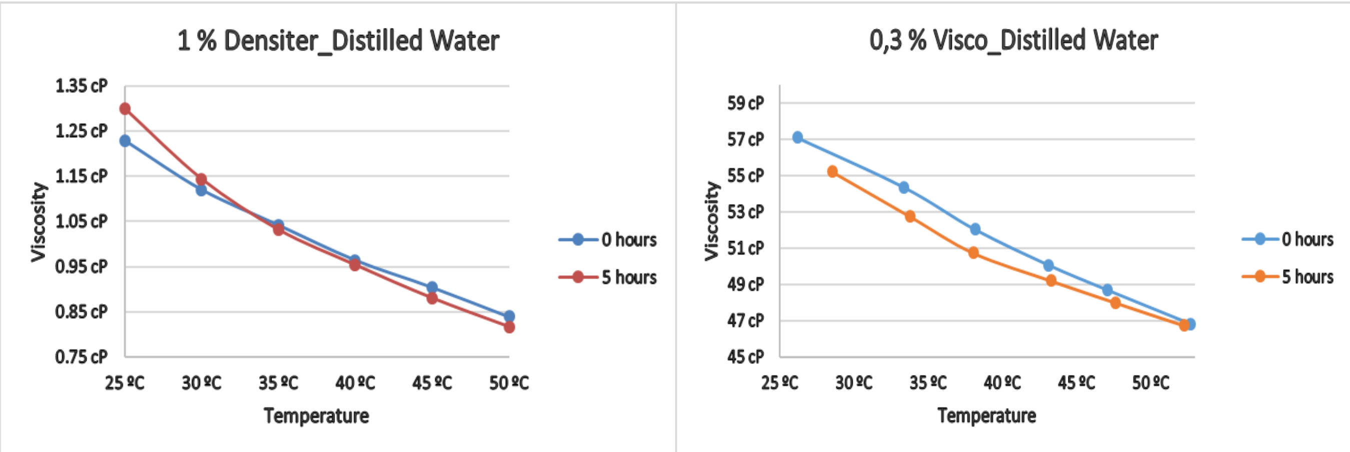

FIGURE 3: Newtonian viscosity behaviour in the same simples without and with a rest period, Densiter®: first-range thickener; ViscoInstant®: second-range thickener.

3.2.2 Nectar consistency

Samples of nectar consistency with first-range thickeners showed a non-Newtonian behaviour at 0 hours and a Newtonian behaviour in the same samples left at rest for 5 hours (Fig. 4). In contrast, all the samples with second-range thickeners showed a Newtonian behaviour independently of the rest time.

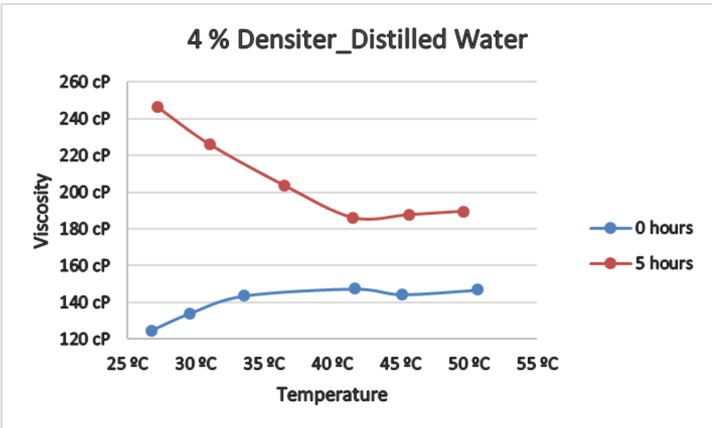

FIGURE 4: Evolution from non-Newtonian behaviour, without a rest period, to Newtonian, with a rest period, from Densiter® first-range thickener at a concentration of 4%.

3.2.3 Honey consistency

The samples just prepared with first-range thickeners showed a non-Newtonian behaviour and these same samples, left to stand for 5 hours, showed a Newtonian behaviour. Fig. 5 shows the behaviour of Densiter® at 5%.

In relation to the behaviour of the second-range thickeners, each thickener presented a different singularity. Thus, Viscoinstant® showed a non-Newtonian behaviour in the newly prepared samples. However, after 5 hours of rest, it showed a Newtonian behaviour up to a temperature of 40ºC. However, at higher temperatures its behaviour was no longer Newtonian.

Regarding Clinutren®, the recently prepared samples showed a non-Newtonian behaviour up to a temperature of 45ºC and up to 40ºC the samples left to stand for 5 hours. The Gelcarin® thickener showed a particular behaviour in comparison with the other thickeners: in the samples just prepared it always presented low viscosities that corresponded to the consistency of a thin liquid. On the other hand, when it was left to stand at low temperatures, its viscosity increased drastically to a honey consistency with a concentration of 0.75% by weight. When the sample was subjected to increases in temperature, its viscosity decreased again to a fine liquid consistency (see Fig. 5).

Finally, Fresubin® behaved more clearly than Clinutren®, showing a non-Newtonian behaviour up to 35ºC in freshly prepared samples and up to 40ºC in samples left to stand for 5 hours.

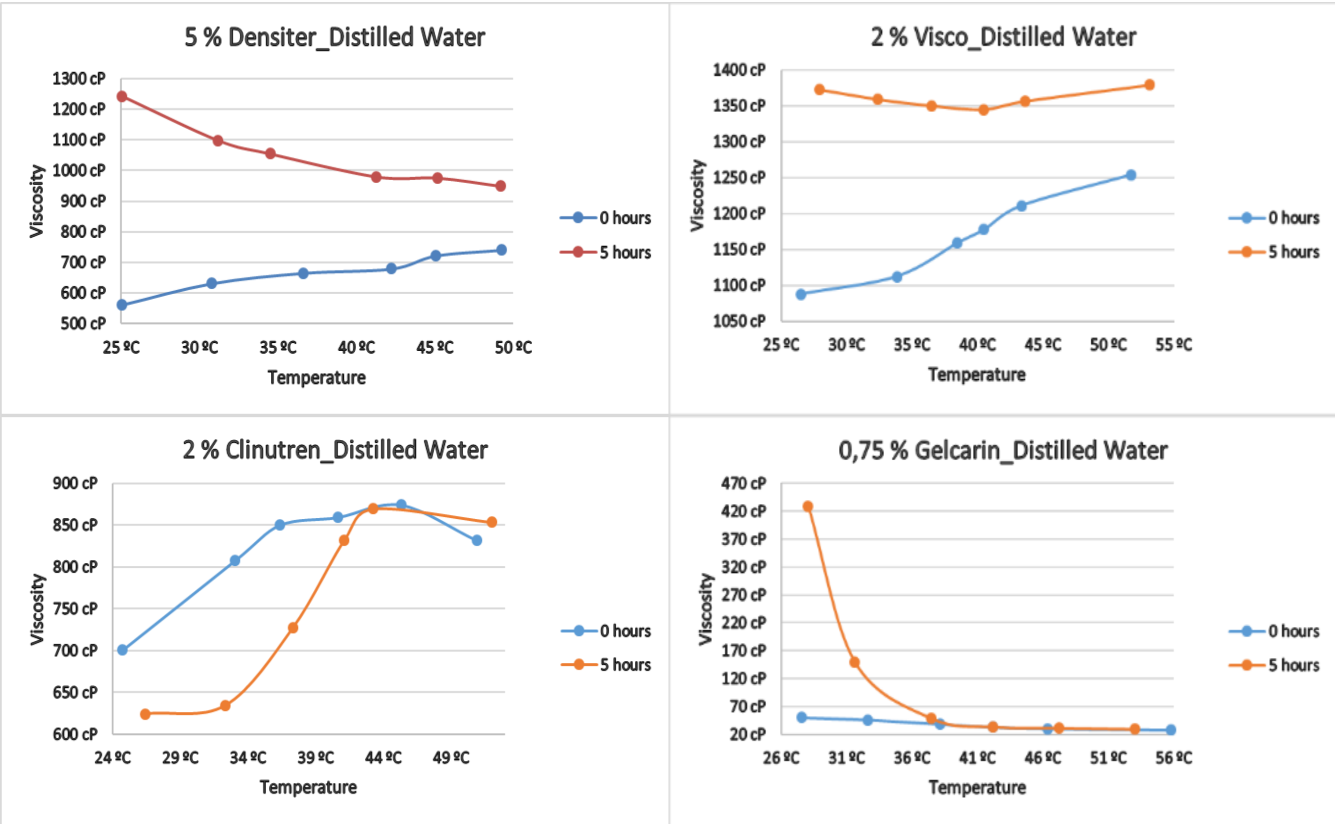

FIGURE 5: Evolution of viscosity behaviour of Densiter®, Viscoinstant®, Clinutren® and Gelcarin® thickeners in the degree of honey consistency without and with a rest period.

3.2.4 Pudding consistency

All the samples prepared with pudding consistency showed a non-Newtonian behaviour, i.e. the viscosity increased with increasing temperature, with the exception of the sample with Gelcarin®. This thickener, with a concentration of 1%, increased its viscosity, from a thin liquid to a pudding consistency, after the resting period. Its behaviour was practically identical to that observed with a concentration of 0.75% and a honey consistency (Fig. 5).

The samples left to stand for 5 hours of the first range thickeners, Densiter® and Resource®, showed Newtonian behaviour, unlike the second range thickeners Viscoinstant®, Clinutren® and Fresubin® which showed non-Newtonian behaviour.

3.3 Interaction of citric acid

Citric acid modified the behaviour of thickeners. The degree of interaction was different in the first-range thickeners from the second-range ones.

3.3.1 Thin liquid

Freshly prepared samples with a thin liquid consistency changed their behaviour due to the introduction of citric acid. First-range thickeners increased the absolute viscosity values, in contrast to second-range thickeners, which decreased these values.

All the samples with the consistency of a thin liquid, when they were left to stand, showed a Newtonian behaviour regardless of the thickener considered. However, the first range thickeners in the presence of acid increased the absolute values of viscosity, while the second range thickeners decreased the absolute values of viscosity. Fig. 6 shows the evolution over time of a first range thickener, Densiter®, and a second range thickener, Viscoinstant®.

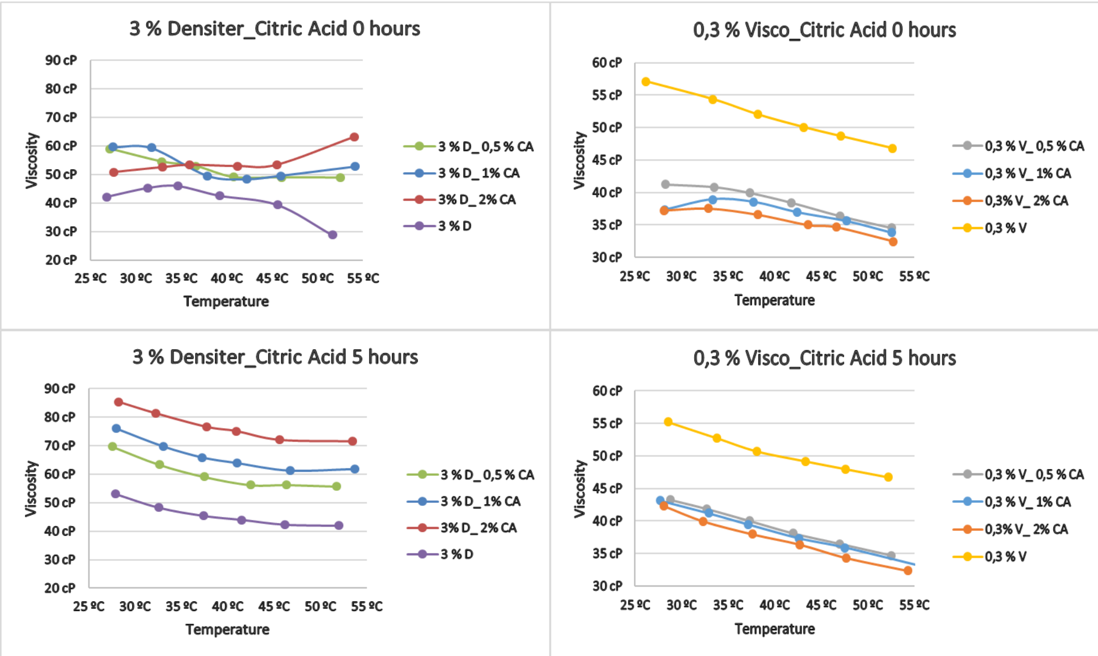

FIGURE 6: Viscosity evolution as a function of temperature and time in samples under the influence of citric acid.

3.3.2 Nectar consistency

The behaviour of the samples just prepared with both types of thickeners in the presence of acid was modified with respect to the samples prepared with distilled water, analogous to the case of the consistency of thin liquid: increase in the absolute values of viscosity in the samples with first-range thickeners and decrease in the second-range.

When the samples were left to stand for 5 hours, all the experimental data series showed a Newtonian behaviour and it was confirmed that the presence of acid in the samples prepared with first range thickeners increased the absolute values of viscosity while in the samples of second range thickeners the viscosity decreased.

3.3.3 Honey consistency

The samples with honey consistency just prepared with Densiter® and Resource® first-range thickeners in the presence of citric acid showed a non-Newtonian behaviour. On the other hand, the samples prepared with the second-range thickeners Viscoinstant® and Clinutren® showed a Newtonian behaviour, whereas the samples prepared with Gelcarin® and Fresubin® showed a unique behaviour, the last one due to its carrageenan-based composition (Fig. 7).

After the 5-hour rest period, Newtonian behaviour was observed in all cases. Furthermore, with the exception of Gelcarin®, the increase in the absolute values of viscosity was confirmed, which determined a change in the behaviour of the thickeners of the second range with respect to that observed in the degrees of thin liquid and nectar consistency.

3.3.4 Pudding consistency

The pudding consistency samples just prepared with first-range thickeners in the presence of citric acid showed a non-Newtonian behaviour. When acid was introduced in the samples just prepared with second-range thickeners, they showed a

Newtonian behaviour, as it had been observed in the honey consistency. Again, with the exception of Gelcarin®, the presence of acid increased the absolute values of viscosity in all cases.

Once the 5 hour rest period was over, a Newtonian behaviour was observed in all cases, confirming the increase in the absolute values of viscosity with acid, with the exception of the samples prepared with the Gelcarin® thickener. It was confirmed that, when the samples were left to rest, they increased their tendency towards a Newtonian behaviour.

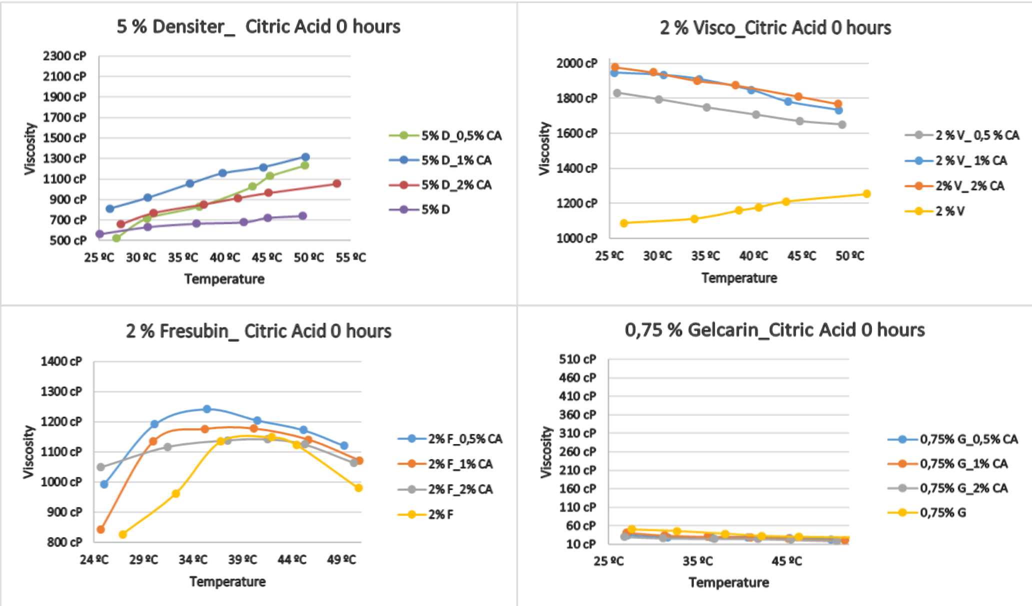

FIGURE 7: Influence of citric acid on samples just prepared with honey consistency.

3.4 pH behaviour study

The possible correlation of pH with viscosity values at different temperatures was studied in order to establish an effect of the acidic environment on the hydration process of thickeners.

Fig. 8 shows that the pH has no direct relation with the variation of the viscosity values. The behaviour of Gelcarin® is shown, the only thickener that presented pH values in the alkaline zone when it was dissolved with distilled water and the behaviour of Fresubin® in the honey consistency. No significant variations of pH are observed compared to the resting time of the samples. This behaviour was observed in all the samples, independently of the thickener used.

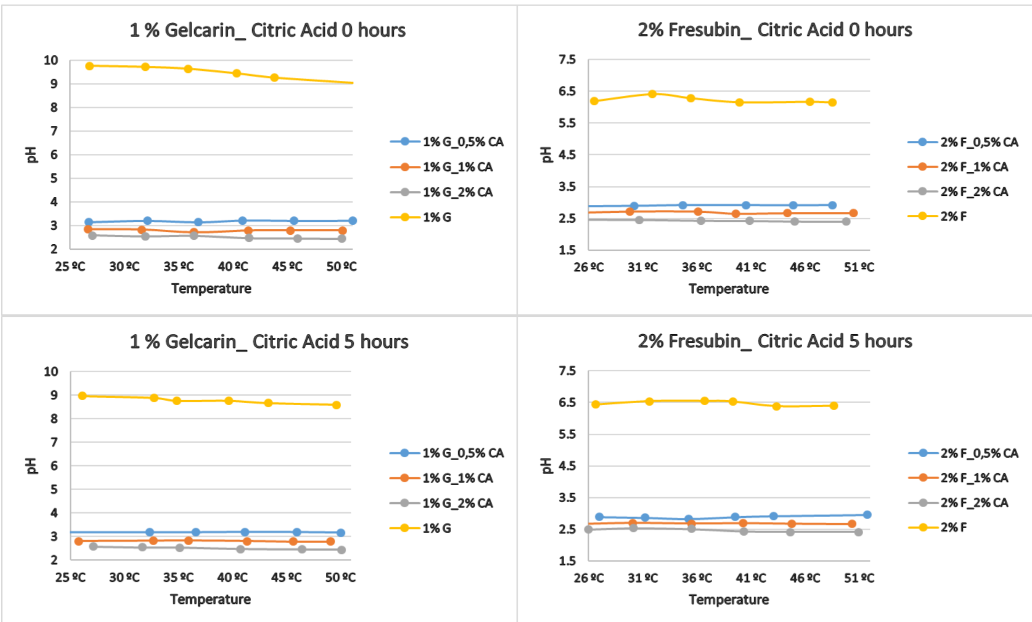

FIGURE 8: pH values in just prepared samples and left to stand for 5 hours of Gelcarin® and Fresubin ®.

IV. DISCUSSION

Substances with the ability to form a gel have been used in the production of processed foods for a long time [15], examples being starch of plant origin and gelatine of animal origin. Chemically complex substances are also used, obtained either from plants or from micro-organisms that are indigestible by the human organism [16,17]. Thus, for example, the unique biophysical properties of alginate, carrageenan and agar are very valuable in the development of functional food products. As food ingredients, the thickening, gelling and emulsifying properties are particularly useful in the application of seaweed hydrocolloids in foodstuffs [18].In general, stabilisers have functional properties that are closely related to their capacity to retain and conserve large quantities of water, which influences the modification of the rheological characteristics of the mixtures [19,20].

The use of thickeners and reduction of intake volumes in patients with dysphagia is a common practice, and an improvement is observed when changing from a fluid consistency (water) to a thicker one (nectar, honey, pudding) [21]. For the functional properties of thickeners to be observed they must be hydrated in water. For effective hydration, it is first necessary to ensure that all the individual particles that make up the dry powder are quickly separated from each other when the water phase is added. Many thickener solutions are pseudoplastic and each has its own characteristics [22,23].

Commercial thickeners used in the treatment of dysphagia present different properties when dispersed in different liquids such as water, coffee, milk or juice [24, 25], influencing sensory perception [26-29].

Although thickeners based mainly on granulated maize starch are widely used in the care of patients with swallowing difficulties, it has been shown that thickened fluids show behaviour that varies over time and are not Newtonian since starch-based thickeners cause a liquid to thicken as the starch molecules swell (hydrate). In contrast, gum-based thickeners cause tangled webs in which water molecules are enclosed [30,31].

In view of the results obtained in this study, it is not recommended to use top-of-the-range thickeners for the treatment of dysphagia due to their sedimentation. This sedimentation took place even in samples treated at 90ºC and was attributed to starch. On the contrary, the second range thickeners gelled resulting in stable gels, results in line with the literature consulted. Other limitations of first-range thickeners were: the formation of lumps and the need for a greater quantity of product to reach the same degree of consistency as second-range thickeners.

Each thickener behaved differently depending on its composition. Moreover, the second range thickeners also showed differences in their behaviour.For instance, Gelcarin® thickener went from a thin liquid consistency to pudding thick and vice versa very quickly depending on the temperature, after a period of rest. This unique behavior is due to the fact that it contains carrageenan – E 407- as the main component. This behaviour is not recommended for patients with dysphagia and is analogous to that described for gelatine [12]. On the other hand, Fresubin® thickener produced foam, behaviour that was associated with the presence of modified cellulose, while Viscoinstant® and Clinutren® thickeners showed similar behaviour due to a very similar composition.

In the presence of citric acid, the absolute values of the viscosities of all thickeners were affected. Unlike the pH values which, for practical purposes, remained constant at variations in temperature and time even in the case of Gelcarin® whose initial pH is in the alkaline zone (the addition of the acid caused a neutralisation of this thickener). That is to say, it was observed that the viscosities of the various thickeners used were not affected by the pH, coinciding with that observed in [32].

In relation to the degree of consistency, the various thickeners showed Newtonian behaviour in samples of thin liquid, i.e. the experimental value of the viscosity decreased as the temperature increased. This behaviour was observed both in the just prepared samples and after a 5-hour rest period.

In the second range thickeners a Newtonian behaviour was also observed in the samples with nectar consistency in all cases. On the other hand, in the samples just prepared with a first range thickener and nectar consistency, a non-Newtonian behaviour was observed, i.e. as the temperature increased, the experimental value of viscosity increased.

For the degree of honey consistency each thickener followed a singular behaviour trend and for the degree of pudding consistency the second range thickeners followed a non-Newtonian behaviour when prepared with distilled water. In all cases, the absolute values of viscosity were higher in the presence of citric acid.

The change in behaviour in the samples just prepared in relation to the samples left at rest was interpreted as proof of the completion of the hydration process of the different thickeners. This hydration was found to be reached after 5 hours in all the cases considered in this study.

The results obtained show that the viscosity of water with commercial thickeners is affected to varying degrees depending on whether they are first or second range. Likewise, the addition of acids, salts or sugars causes a change in their behaviour which can affect the swallowing capacity of the resulting mixtures [33-35].

V. CONCLUSIONS

There is a direct correlation between the concentration of thickener and the degree of consistency. This fact indicates that rigorous monitoring of the relevant indications is required when preparing a standard sample since, if no rigorous action is taken, there is a risk of aspiration into the lung.

First range thickeners sediment when left to rest as a result of the high percentage of starch present in their composition. As the temperature increases, the starch swells and thickens, while the hydrocolloids containing gums in their composition (especially xanthan) remain stable.

So called second-range thickeners, which are made exclusively of gums and in some particular cases may contain a small amount of modified starch, allow a significantly lower amount of product to be used to obtain the desired viscosity, especially in the nectar and honey consistency grades, so that the visual appearance and taste of the thickened liquid is modified to a lesser extent.

It is proposed to extend the study of the interaction of thickeners with other food substances in order to achieve their purpose.

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